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SUMMARY OF THE STUDIES ON THE CORRELATION PHENOMENA AMONG THE CHARACTERS OF THE RICE PLANT AND ITS APPLICATION IN PRACTICE

By

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Dr. Eikichi Iso has gained wide reputation through his work of 35 years long on the breeding and culture of rice. It is largely due to his contribution that the foundation of the improvement of rice crop in this island has been solidly laid. The present volume is a summary of his researches on the correlation phenomena of rice plants which constitute the basic knowledge to the crop improvement.

I have this volume printed for the benefit of the workers in this field.

Lee Ling, Director
Taiwan Agricultural Research Institute
Taiwan, China
1946

PREFACE

Recently I have had many chances to speak, in the fragmentary way, about rice culture in TAIWAN, as I was asked to do so by those who were engaged in the technique of rice culture. But these talks were merely no more than common sense. It seems there is little what reaches the standard scientifically inspecting the technique of rice culture in TAIWAN and also attempting its development. Till today, in TAIWAN there has been a considerable accumulation of scientifically technical knowledge. This essay, at least, is the elementary guide.

In order to understand the further details on Taiwan- rice culture I have Literature 35, which is in preparation for printing. I have made this elementary extract of it for the understanding and convenience of all concerned. If you would understand this humble desire of mine, I should be greatly fortunate.

Eikichi ISO

April, 1946.

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SUMMARY OF THE STUDIES ON THE CORRELATION PHENOMENA AMONG THE CHARACTERS OF THE RICE PLANT AND ITS APPLICATION IN PRACTICE

By

Eikichi ISO

I. THE STUDY OF THE CORRELATION OF THE FACTORS WHICH HAVE A CLOSE RELATION TO THE YIELD OF GRAIN

The most important point for the rice producers to get is not only the high yields and good qualities of the grains but the most economic way. The yield and the quality, however, are the synthetic results of many influencing factors. During the period of the whole life of the plant, it is not one or two characters that might make absolute determinations. This is the reason why we ought to study the phenomena of the correlation occurring among these characters of the plant which influence as a final results the increase or decrease of the yield.

The investigation of several studies of the correlation of the rice plant has been reported, but for the greater part these reports are based upon the characters among the different varieties. The writer has also studied these correlations, as is shown in Table 1, but these correlations do not show the real factors which determine the correlation of the physiological phenomena so far as is known. From different view-points the characteristics are often reversed within the results of differentiation from the pure line.

It would seem, therefore, that some definite directed research of correlation of the characters of a pure line would be of greater value in this field. The writer chose varieties to experiment seven pure lines which were derived from the seven representative Formosan native varieties of the first crop and seven from the second crop. The experiments were carried out in the experi-

mental field and laboratory where about 6,000 correlation coefficients were calculated among foreign characters (1920–21). Among those coefficients the combinations in Table 2, have shown remarkable correlation and six (※) were selected as having direct relation to the yield of grain. The response of tillering and the weight of ear should be studied as to the characteristics of variety in connection with the final point.

TABLE. 1. The correlation phenomena among the characters within varieties of the Rice plant.

Between the characters X and Y		Correlation Coefficients	
X	Y	First Crop	Second Crop
Length of culm	Number of tillers	− 0.078±0.079	− 0.375±0.071
〃	Length of ears	+ 0.599±0.052	+ 0.931±0.068
〃	Weight of ear	+ 0.474±0.058	+ 0.670±0.046
〃	Number of unhulled grains per ear	+ 0.410±0.068	+ 0.635±0.060
〃	Number of grains per unit length of ear	+ 0.105±0.080	+ 0.557±0.057
〃	Weight of unhulled grains per ear	—	− 0.014±0.082
Number of tillers	Length of ear	− 0.062±0.080	− 0.219±0.078
〃	Weight of ear	− 0.426±0.065	− 0.641±0.049
〃	Number of unhulled grains per ear	− 0.431±0.065	− 0.552±0.057
〃	Number of grains per unit length of ear	− 0.379±0.069	− 0.554±0.058
〃	Weight of unhulled grains per ear	—	− 0.100±0.082
Length of ear	Weight of ear	− 0.037±0.080	+ 0.921±0.013
〃	Number of grains per ear	+ 0.240±0.076	+ 0.576±0.055
〃	Number of grains per unit length of ear	− 0.240±0.076	+ 0.143±0.014
〃	Weight of unhulled grains	—	− 0.023±0.082
Weight of ear	Number of grains per ear	+ 0.877±0.186	+ 0.920+0.012
〃	Number of grains per unit length of ear	+ 0.736±0.037	+ 0.694±0.042
〃	Weight of grains per ear	—	+ 0.000±0.081
Number of grains per ear	Number of grains per unit length of ear	+ 0.872±0.020	+ 0.911±0.014
〃	Weight of grains per ear	—	− 0.241±0.078
Number of grains per unit length of ear	Weight of unhulled grains	—	− 0.270±0.076

TABLE. 2. The summary of the correlation phenomena among the characters within pure line of the Rice plant. (1921-23, 1932,1941).

Between the characters X and Y		Correlation Coefficients	
X	Y	First Crop	Second Crop
Yield of unhulled rice	※Total dry weight of the plant	+ 0.56	+ 0.72
〃	※Number of tillers	+ 0.61	+ 0.82
〃	※Weight of ear	+ 0.35	+ 0.53
〃	※Length of ears	+ 0.39	+ 0.39
〃	※Number of grain per ear	+ 0.37	+ 0.60
〃	※Number of grains per unit length of ear	+ 0.31	+ 0.50
Number of tillers	Number of available tillers	+ 0.75	+ 0.67
〃	Available tillers ratio to the total tillers	− 0.26	− 0.35
Number of tillers during the early period of growth	Number of available tillers	+ 0.53	+ 0.45
Order of tillering	Days of growth period	− 0.92	− 0.89
〃	Order of heading	+ 0.37	+ 0.61
〃	Length of culm	− 0.44	− 0.64
Days of growth period	Length of culm	+ 0.37	+ 0.52
〃	Length of ear	+ 0.38	+ 0.44
Length of culm	Weight of ear	+ 0.38	+ 0.62
〃	Numher of tillers per plant	Very remarkably positive during the early stage, +0.549 ±0.067 in the first crop +0.641 ±0.039 in the second crop and they decrease gradually in a later stage, sometimes remarkably in negative.	
Length of root	Length of culm	+ 0.79	+ 0.84
Extension of the root system	Length of culm	+ 0.77	+ 0.78
Number of roots	Number of culm	+ 0.79	+ 0.98
Weight of root	Weight of upper ground part of the plant	+ 0.88	+ 0.98
Days of nursery period	Length of culm	− 0.61	− 0.88
〃	Number of tillers	− 0.38	− 0.53
〃	Days from sowing to heading	+ 0.72	+ 0.89
〃	Days from transplanting to heading	− 0.82	− 0.99
〃	Standard deviation of heading	+ 0.76	+ 0.70
〃	Yield of unhulled rice	− 0.89	− 0.82
〃	Total carbohydrates of seedlings (%)	+ 0.52	+ 0.64
〃	Total nitrogen of seedlings (%)	− 0.77	− 0.88
〃	Carbon-Nitrogen Ratio	+ 0.90	+ 0.59
Position of ratoons from lower to upper node of the culm	Carbon-Nitrogen Ratio	—	Positive
Order of stages of growth	Carbon-Nitrogen Ratio	Remarkable positive as a whole, but negative at the stages of excellent growth and heading	

Remark:- These data are the modes of the fluctuations of the correlation coefficients.

II. EXAMPLES OF THE RESULTS IN PRACTICAL WORK

1. A result in the pure line selection during the years 1915–19.

The author and others worked out a pure line selection, using 15 varieties of the first crop and 15 varieties of the second crop. They selected one superior pure line of each variety (30) which was distributed to the growers.

The characters of these lines were studied and it was found that these lines excelled other lines which were already comparatively excelled lines in

(1) tillering
(2) weight of kernels
(3) length of ear
(4) grain ratio to kernels
(5) number of kernels per unit length of ear.

All characters except tillering can be recognized as factors which constitute the weight of ear. In the end these results show that the tillering and the weight of ear were the most important characters of the yield.

In the work of selection, three preliminary selections are usually made in the fields:—

a. Made in the period from transplanting to available tillering stage.
b. Made in the period from transplanting to maximum tillering stage.
c. Made in the heading stage.

When they are compared with final results after harvesting, the excelled pure lines are more likely to be the first preliminary selection, which is the early growth period.

TABLE 3. The effect of preliminary selection in early growth period.

Crop season	Order of preliminary Selection	Number of Pure Lines Selected Preliminary in the Field	Number of Selected Pure Lines	
			Actual Number	% to the Preliminary Selection
First crop	1	1500	578	38.6
	2	—	—	—
	3	241	53	22.0
Second crop	1	178	101	56.7
	2	1202	453	37.7
	3	120	55	45.8

2. The influences of length of nursery period to the tillering, weight of ear, heading and other characters.

This experiment was repeated 16 times in the experimental fields and so were many other trials of the same kind in the local fields during the years 1920-26. As a whole, almost the same results were worked out recommending the practical method to the general rice growers. This method has been worked out with great success in connection with Japanese varieties in Formosa where many experiments had practically failed to grow during the past 30 years, although even great efforts had been made to produce.

The reader may recognize the following results by the correlation coefficients in the Table 2.

a. Days from sowing to heading are to be decreased or increased according to decrease or increase of the days in the nursery period.

b. Days from transplanting to heading are to be increased or decreased according to decrease or increase of the days of nursery period.

c. The uniform heading is to be found in the plant which is derived from a short nursery period and the deviation of heading is always larger in the plant which is derived from a longer nursery period.

d. The number of tillers is likely to be increased according to a shorter nursery period. It is not so remarkable in the second crop as in the first crop, but sometimes there is an increased number according to a longer nursery period.

However these tillers had practically been found to have fallen behind in heading and to have grown abnormally.

In general we may arrive at the following conclusion :-

The young nursery seedlings are more likely to prolong the growth period, increase the length of culms and the number of tillers, make uniform heading, produce good quality of grains, increase the weight of ear and finally increase the yield of grain.

The writer found that these phenomena were more remarkably responsive in the second crop than in the first. The earlier variety is more responsive

than the later variety, and in the southern tropical part more responsive than in northern temperate. These probably depend upon differences of physiological responses of varieties as well as differences of environments in regard to different cultural seasons and localities.

For instance suppose if there should be some difference of carbon-nitrogen ratio of contents between young and old seedlings or between early or late tillering of the plant. We should expect some differences of growth of top and root. Also we should expect some deeper meaning when these seedlings respond to the different environment, such as in the first or second crop season.

Therefore we should be interested in studying what physiological condition must hold in the soil in the early stages of the growth period after transplanting in order to produce a large yield of grain. The writer found (1931) that Carbon-Nitrogen Ratio of young seedlings always is lower than that of old seedlings and within the same number of days of nursery period, ratios of seedlings in the second crop season always higher than that of the first crop season, on account of environmental condition that is the combination of temperature and day length. Table 4.

Among the correlation coefficients we find

1. Dry-weight per plant correlates with the number of tillers.
2. Length of ear, number of kernels in a unit length of ear correlate with the weight of the ear.

Consequently, as a whole, we may arrive at the conclusion that the yield of kernels consists of the number of tillers and weight of ear. Therefore, it is most important to study the nature of these two characters.

TABLE 4. Carbon Nitrogen Ratios of seedlings showing their ages.
First Crop, 1931, Variety Kagi Ban No. 2

Contents of seedlings	Days of nursery period				
	40	45	50	55	60
Total Nitrogen %	5.850	5.627	5.296	4.733	3.831
Total Carbohydrates %	15.772	22.713	25.026	24.996	22.580
Carbon Nitrogen Ratio	2.696	4.036	4.724	5.281	7.721

Second Crop, 1931, Variety Kagi Ban No. 2.

Contents of seedlings	Days of nursery period						
	10	15	20	25	30	35	40
Total Nitrogen %	5.009	4.750	3.387	3.306	3.132	2.793	2.575
Total Carbohydrates %	16.854	18.337	20.961	19.153	21.086	22.693	27.134
Carbon Nitrogen Ratio	3.365	3.860	6.189	5.793	6.732	8.125	10.541

First Crop, 1942.

Variety	Contents of seedlings	Days of nursery period					
		30	40	50	60	70	80
Chungtzong	C	24.248	27.208	24.843	39.320	36.942	35.339
	N	6.259	4.261	4.085	3.505	2.275	2.354
	C/N	3.874	6.384	6.082	11.229	16.238	16.196
Taichung No. 65	C	20.388	24.472	29.301	34.875	31.521	28.783
	N	6.051	4.474	4.449	2.755	2.824	2.355
	C/N	3.369	5.470	6.586	12.659	11.162	12.222
Chianan No. 2	C	20.345	24.569	31.631	33.808	33.264	36.840
	N	5.269	5.276	4.942	2.942	2.354	2.701
	C/N	3.842	4.569	6.400	11.492	14.131	13.639

Second Crop, 1942.

Variety	Contents of seedlings	Days of nursery period						Time of heading on the nursery	
		15	20	25	30	35	40		
Chungtzong	C	22.723	23.674	24.472	30.078	28.029	25.284	34.240	60 th Day
	N	5.180	3.507	3.509	1.801	1.500	1.404	2.058	
	C/N	4.386	6.750	8.000	16.701	18.686	18.009	16.637	
Taichung No. 65	C	23.483	22.729	24.037	30.618	29.417	23.157	38.641	74 th Day
	N	6.513	3.876	3.223	2.249	2.050	1.556	2.043	
	C/N	3.606	5.863	7.458	13.614	14.350	14.882	18.913	
Chianan No. 2	C	19.051	20.892	27.925	30.098	33.214	32.978	44.029	90 th Day
	N	7.110	3.687	3.809	2.089	1.998	1.478	2.244	
	C/N	2.680	5.666	7.331	14.761	16.824	22.313	19.621	

Remark:- C Total Carbohydrates %
N Total Nitrogen %
C/N Carbon Nitrogen Ratio

III. TILLERING

It is almost a rule that one part of the tillers of a plant grows to the heading and produces the ears, but the other part does not grow to the heading. The former are called available tillers and the latter which die out are called non-available tillers. When the Taiwanese varieties are transplanted in the first crop season in Taiwan, the rice roots appear five days after transplanting and grow in length after ten days and they begin tillering after fifteen days. In the second crop season the roots appear one day after transplanting, grow in length after five days and begin tillering after ten days. Usually the period of the available tillering in the first crop season is 45 days after transplanting and 35 days in the second crop season. The maximum number of days of tillering is 60 days in the first crop season and 50 days in the second crop season. (1916)

The growth of culms followed by the growth of the rice may be divided into three stages in the case of the first crop: the stage to the beginning of tillering after transplanting (the period of stand-fixed of seedlings after transplanting), the stage to the maximum of tillering after the beginning of tillering (rapid growth), and lastly that after the maximum of tillering. In the case of the second crop there are two stages: the stage to the maximum of tillering after transplanting (as the stand-fixed of seedling is rapid and the time to begin the growth of culm comes rapidly, the growth of the above-mentioned first stage is not clear and then one can see the development of the second stage at once) and secondly the stage after the maximum tillering.

In both of the two crops one can see the growth to stop for a while about at the maximum tillering. This period coincides with the period of the growth of pregnant ears within culms. After this period the rapid growth of culms corresponds to heading (1916, 1941).

As far as heading is concerned, it takes 60–70 hours from its beginning to the end and there is an inclination that in the second crop it takes less time than in the first crop. Generally it takes ten days or so for the heading in a clump.

Of the progress of heading in one day, it is rather slow from midnight to the early morning, and it gets rapid in the daytime. Moreover, heading is rather ununiform in the first crop than in the second crop. For instance, if you take each fifteen pure line varieties in both crops, standard deviation is ± 2.152 days in the first crop and ± 1.352 days in the second crop (1917–18).

As far as the order of heading in a clump is concerned, in the case of early tillering though it takes many days till the time of heading, the time of heading comes early; in the case of slow tillering the number of days is smaller but the time of heading comes lately.

And in the second crop this inclination is more striking than in the first crop. When it takes many days from tillering to heading, length of culms and length of ears become long (1916).

Roots:— The increase of the number of roots generally follows the growth of the aerial part. The degree of the increase is small in the early stage and new roots spring up abundantly after the maximum of tillering. Accordingly the number of roots increases and it reaches the maximum about at the time of heading. After that time, they decrease towards the time of maturity. This owes to the decrease of the appearance of new roots and to the withering and rottenness of old roots.

The increase and decrease of the weight of roots runs parallel with the increase and decrease of the number of roots. The ratio of the number of new roots to the number of the whole roots is generally larger in the first crop than in the second crop but in both crops this ratio is large at the time of transplanting and afterwards it becomes small. After the maximum of tillering new roots grow abundantly, but also old roots increase. So that the ratio moves between 30% and 40% but the increase or decrease is not conspicuous. After the heading the ratio of new roots to the whole roots rapidly falls down because of the decrease of the appearance of new roots.

The conditions of the growth of roots may be divided by the maximum of tillering: before that maximum roots develop sideway near the surface of the soil and after the maximum they develop deeply downwards.

About at the time of pregnant stage of ear the territories of roots are generally decided and they reach the maximum at the time of heading (i. e. 46.2 cm in the first crop, 45.2 cm in the second crop) and are going to respond to the growth of the aerial part. That is, in the period from the beginning of tillering to the pregnant stage of ear the activity of roots is most striking and the absorption of the elements of fertilizer is mostly carried on during this period.

The number of roots per culm does not change so much until the maximum of tillering. After that the number of roots rapidly increases and becomes greatest about at the time of heading (i. e. Taichu No. 65, 200 roots in the first crop, 84 roots in the second crop), and then it gradually decreases towards the period of maturity. After the maximum of tillering one can see such an inclination that the more the number of culm is, the less the number of roots per culm is. This fact explains that the more the tillering is, the more nonavailable tillers grow (1941).

TABLE 5. Root development in general culture of the Horai rice in the first crop, 1945.

Days after transplanting	Length of roots in horizontal radius, cm.	Length of roots in depth, cm.	Soil layer in depth where roots are most distributed, cm.
20+	13–15	6– 8	2– 5
35卄	18	15	5–10
55卅	23–25	16	15
75卌	No increase as it is		

REMARKS:—

\+ { 15 cm. layer of cultivated soil in general.
23–25 cm. from a clump is right under neighbouring clumps.

卄 { 16 cm. layer of subsoil.

卅 { Number of roots per culm is about 40 and is to be found in maximum number in the growing period.
Roots are to be hindered from growth at the subsoil layer and bent spiral or branched irregular, entering in the subsoil,about 20–25 cm. in depth.
Few distribution of own roots right under the clump, but under neighbouring clumps.

卌 { Roots in the surface soil are to live as it is.
Roots running slant direction are to be destructed.
Roots running downwards are to live remained and increased in length about 40 cm. into subsoil.

TABLE 6. Frequency table showing variation in Coefficient of Correlation (1921-23).

Correlation Coefficient between (Combination of characters)		Frequency. Number of Coefficients																					
		Order of tillering and Days of growth period				Order of tillering and Order of heading				Days of growth period and length of culm				Days of growth period and length of ear				Order of tillering and length of culm				Length of culm and weight of ear			
First or Second crop		1st		2nd		1st		2nd		1st		2nd		1st		2nd		1st		2nd		1st		2nd	
Positive (+) or Negative (−)		(+)	(−)	(+)	(−)	(+)	(−)	(+)	(−)	(+)	(−)	(+)	(−)	(+)	(−)	(+)	(−)	(+)	(−)	(+)	(−)	(+)	(−)	(+)	(−)
Class Value of Correlation coefficient	0.0	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	3	−	−	−	−	−	−
	0.0 — 0.1	−	−	−	−	11	10	−	−	14	6	5	1	19	4	1	4	3	9	−	3	3	3	−	−
	0.1 — 0.2	−	−	−	−	15	4	5	−	18	6	13	2	14	1	17	2	3	7	−	3	4	2	−	−
	0.2 — 0.3	−	−	−	−	22	2	8	1	20	4	10	−	20	5	18	3	4	18	1	4	6	−	−	−
	0.3 — 0.4	−	−	−	−	24	4	18	−	27	3	17	−	26	2	30	1	3	24	−	8	14	−	−	−
	0.4 — 0.5	−	−	−	−	33	2	18	−	16	2	30	1	34	2	28	−	2	30	−	19	13	−	−	−
	0.5 — 0.6	−	−	−	−	28	1	29	−	34	2	39	−	30	−	51	1	−	33	−	33	42	−	−	−
	0.6 — 0.7	−	1	−	2	21	−	46	2	26	2	47	−	26	1	35	−	−	36	−	44	36	−	−	−
	0.7 — 0.8	−	3	−	17	21	−	36	−	18	−	31	−	16	−	9	−	−	19	−	57	38	−	−	−
	0.8 — 0.9	−	56	−	80	10	−	33	−	8	−	8	−	4	−	7	−	−	11	−	33	87	−	−	−
	0.9 — 1.0	−	149	−	108	1	−	11	−	2	−	3	−	3	−	−	−	−	2	−	2	9	−	−	−
(+) (−) No. of Individuals			209		207	186	23	204	3	183	25	203	4	192	15	196	11	15	192	1	206	202	5	−	−
Total No. of Individuals		209		207		209		207		208		207		207		207		207		207		207		−	
Correlation Coefficient	Maximum	− 0.869 ± 0.009		− 0.864 ± 0.008		+ 0.672 ± 0.016		+ 0.674 ± 0.016		+ 0.383 ± 0.034		+ 0.627 ± 0.016		+ 0.390 ± 0.024		+ 0.550 ± 0.019		− 0.477 ± 0.022		− 0.649 ± 0.016		+ 0.885 ± 0.007		−	
	Minimum	− 0.781 ± 0.013		− 0.717 ± 0.016		+ 0.202 ± 0.036		+ 0.406 ± 0.021		+ 0.143 ± 0.040		+ 0.299 ± 0.028		+ 0.116 ± 0.037		+ 0.219 ± 0.029		− 0.222 ± 0.036		− 0.341 ± 0.029		+ 0.426 ± 0.027		−	

TABLE 7. Index in 100, showing the yielding abilities of the mother culm and the tillers, average of three varieties, Chungtzong Taichung No.65, Chianan No. 2, 1943.

Crop season	(1) Number of tillers in each class order per clump: total number of tillers per clump.			(2) Number of headed ears of each class order per clump: Number of tillers in each class order per clump			(3) Weight of ear			
	Prim. till.	Sec. till.	Tert. till.	Prim. till.	Sec. till	Tert. till.	Mother culm	Prim. till.	Sec. till.	Tert. till.
First Crop	71	100	15	100	70	16	100	84	61	44
Second Crop	76	100	10	100	85	82	100	97	58	41
Average	73.5	100.0	12.5	100	77.5	49.0	100.0	90.5	59.5	42.5

Crop season	(4) Number of grains per ear				(5) Yielding abilities (1) × (2) × (3)		
	Mother culm	Prim. till.	Sec. till.	Tert. till.	Prim. till.	Sec. till.	Tert. till.
First Crop	100	78	66	41	100	44.4	9.8
Second Crop	100	74	56	40	100	68.6	6.8
Average	100.0	76.0	61.0	40.5	100.0	56.5	8.3

Prim. till....Primary tillering class
Sec. till....Secondary tillering class
Tert. till....Tertiary tillering class

TABLE 8. Index in 100, showing the yield capacities of the mother culm and tillers in the results of high yielding competition in general, 1944.

Crop season	Yield capacities per clump, Index in 100		
	Mother culm	Primary tillering class	Secondary and Tertiary tillering class
First Crop	30 or so	70 or so	Trace
Second Crop	35 or so	65 or so	Trace

Correlation studies of the factors which influence the tillering in a pure line in all stages of growth consist of:-

1. Number of tillers and number of available tillers
2. Time of tillering, early or later and available tillering

3. Time of tillering and the number of days of the growth period of all culms
4. Deviation of tillering and deviation of heading
5. The tillering and length of culms in all stages of growth.

These are shown in Table 2 and 6. The factors which influence tillering may be explained as follows:-

Correlation coefficients between the number of tillers and the number of available tillers are found to be very remarkably positive. Coefficients between the number of tillers and the available tillers ratio to the total tillers are found to be remarkably negative and therefore the more tillers the plant produces during the growth period, the more available the tillers are. But the ratio will decrease according to the increase.

The correlation coefficients between the order of tillering and the number of days of growth period which means from the day of tillering to heading or from the day of transplanting to heading, are found to be very remarkably negative and the mode in their frequency distribution has almost a complete negative position and therefore the early tillered culm has a longer growth period; each successive culm has a comparatively shorter growth period. To let only the mother culms and the first primary tillered culms in unit area grow, controlling successive tillering, is a secret key to get the highest yield of grain. (Table 7, 8)

For this purpose, optimum spacing of transplanting is needed. Theoretically, experimental result shows, when 350-400 seedlings are transplanted each apart square way occupying the same area per plant, it gives the highest yield and earlier heading than usual. But such procedure is nearly impossible in practice. Therefore it is recommended that 4～5 seedlings per clump, 70～80 clumps or so per *tsubo* (3.3 m^2) and 350～400 seedlings in total per *tsubo* should be transplanted. Also, the writer always found that he could keep the damage by rice brust disease low with this spacing though he couldn't scientifically explain the reason.

Correlation coefficients between the number of tillers and that of available

tillers during the early period of growth are found to be very remarkable and therefore this function of earlier tillering produces more available tillers.

Coefficients between number of tillers and length of culms in all stages of growth, are found to be very remarkably positive during the early stage and they decrease gradually in a later stage; therefore the earlier tillering produces a taller culm and better growth.

Correlation coefficients between the order of tillering and the order of heading are found to fluctuate from positive complete to a very remarkable negative, but in their distribution we may find the number of positive variates to be eight times the number of negative variates in the first crop and 68 times in the second crop. The modes are in a very remarkable positive position in the first crop and in an extremely remarkable positive position in the second crop. Therefore, the earlier the tillering, the earlier the heading and the smaller the deviation of the tillering, the smaller the deviation of the heading. A striking difference of this phenomenon is found between the first and the second crops. This is shown more remarkably in the second crop. This is probably a result of difference of environment during the two crop seasons.

IV. WEIGHT OF EAR

A study of the correlation phenomena of the factors which constitute the weight of the ears between each two characters as follows:

1. Days of growth period and length of culm
2. Time of tillering and length of ear
3. Time of tillering and length of culm
4. Time of tillering and weight of ear
5. Length of culm and weight of ear
6. Length of culm and weight of grain
7. Deviation of heading and weight of ear.

The characters which have a direct relation to the weight of the ear are:—

1. Length of ear

2. Number of kernels
3. Number of kernels in unit length of ear
4. Size of kernels
5. Grain weight ratio to the kernels
6. Enrichment of content of kernels.

The correlation coefficients between the days of growth period and length of culm or length of ear are distributed from almost a complete positive to a remarkable negative. But the number of positive variates of the length of the culm is 7 times the number of the negative variates in the first crop, and 51 times in the second crop. The number of positive variates of the length of the ear is 13 times the negative variates in the first crop and 18 times in the second crop. All modes are placed in a very remarkable positive position and the correlation is more remarkable in the second crop than in the first crop (Table 6). Probably it is caused by the differences in environments.

The writer cannot give the results of the ear weight in the same series of the first crop on account of disease disturbances. But fortunately he can present the results derived from different experiments which show $+0.38 \pm 0.057$ in an average of 31 cases and at the same time worked out $+0.305 \pm 0.060$ between length of culm and length of ear, $+0.636 \pm 0.036$ between length of ear and weight of ear (1922). Therefore we may say there is the same correlation in the first crop as in the second crop.

If the time of tillering is rapid or early, the culm is taller. On the contrary if the culm is short, the weight of the ear is light and consequently in the case of mixing many ears fall behind in the heading. It causes the decrease of the average weight of ear in a plant. The correlation between the order of tillering and the order of heading is very remarkably positive (Table 6). The ear which falls behind in heading causes ununiformity of heading. On the contrary, when the heading is uniform, less ears fall behind in the heading and this causes the average weight of ear to increase. Also, uniform heading causes uniform ripening which brings a good quality of grains.

Another process which proves the positive correlation between earliness of heading and weight of the ear, was the study of the weight ratio of the grain and straw of the tallest culm and the weight ratio of the grain and straw of the shortest culm. An average ratio of 7 varieties of the first crop was found to be 106.68±1.35 in the tallest culm, 102.66±1.62 in the shortest culm. The average ratio of 7 varieties of the second crop was found to be 102.56±1.43 in the tallest culm and 98.27±1.49 in the shortest culm (1922). From the former explained result, such as the tall culm derived from early tillering, we may expect that early tillering causes the increase of weight ratio of grain to straw, and late tillering causes the decrease of the economical weight of the ear of the plant.

For example, it has been found:

1. Correlation coefficient between height of culm and weight of hulled grain was, in the first crop, +0.362±0.034 (1924) and +0.249±0.038 (1919).

2. The average height of culm of 150 pure lines which were derived from 15 varieties of the second crop was 114.8 cm and the average weight of grain which was produced by those culms was 16.81 gm. in a thousand grains. This was worked out in 1917, but in the year 1918 the average height of culm was 100.4 cm and the average weight of grain was decreased to 16.07 gm.

3. In 1924 there was a culture of 181 Japanese varieties in the experimental field. In this year it was found that the average height of the culm was 111.6 cm and the average weight of grain in a thousand grains was 23.47 gm. This was the result of the first crop. But in the second crop the height decreased to 94 38 cm and the weight decreased to 22.11 gm.

Therefore, we may recognize that the heavier grain is more likely to be produced in the taller culm.

Now we are able to talk about another look at the results of the experiment. It is to be recognized that there are several characters which have some remarkable difference of response in the correlation phenomena between the first and second crops.

The rice crop season in TAIWAN is divided into 3 large groups, first, second, and intermediate seasons. We usually call these crops the first, second, and intermediate crops.

The first crop is to be sowed and transplanted in a low temperature and short day period, in fall, winter or early in the spring, and to be harvested in the maximum temperature and long day period of summer.

The second crop is to be sowed and transplanted in the maximum temperature and long day period in summer and to be harvested in a low temperature and short day period in the late autumn.

The intermediate crop is to be planted between these two seasons. It is common in favorably irrigated land to harvest 2 crops, the one of the first and the one of the second in one year. But, however, the first is to be grown along with the ascending temperature through all its life stages. The second crop is to be grown along with descending temperature through all its life stages. The length of day is to be increased from the minimum to maximum during the growth period of the first crop and decreased from maximum to minimum in the second crop. Therefore, we should expect the differences of physiological response and structural changes of cell or tissues of the plants according to different characteristics of varieties of the rice,—the rice which, as a whole, belongs to the short day plant—and according to different environments. Here we ought to consider what stages of the growth period of the rice in each season must be most important and what process must be used in practice to get high yield and good quality of the grains.

V. THE KEY OF APPLICATION OF EXPERIMENTAL RESULTS IN PRACTICE

The results of the experiments show that there are two important factors which determine the yield of grains. They are the tillering and the weight of the ear, the processes which accelerate tillering and bring the decrease in the deviation of tillering after transplanting. This is the key by which one may have good yield and good quality of the grains.

On the side of plant breeding the process is to breed or select the plant in regard to heavy ear and excellent nature of the tillering, which means not only number of tillers but tillering tendencies.

Sometimes it may be difficult to get such a complete variety, so in selecting a variety which is excellent in the one character, one has to keep in mind the fact that the loss of the other character is to be overlooked in the gain of the superior character. One should also study other indirect characters which have close relation to the yield of the grain such as:—(1) Length of ear (2) number of kernels of an ear (3) number of kernels per unit length of ear (4) weight of kernels. Because of many kinds of calamities, which disturb the experimental results, one should watch all the above points in order to make one's work safe.

On the side of cultural processes the final points should be maximum weight of ears per unit area or in some cases it may be maximum length of the total ears per unit area. All cultural processes should be watched carefully such as: (1) Proper season of transplanting (2) proper young seedling (3) proper spacing and depth of planting (4) kind and quality of fertilizers (5) time and method of fertilizing (6) proper depth of irrigation water (7) proper number of weeding (8) treatment of the farm soil (9) system of cultivation.

(1) **Proper season of transplanting.**

The first crop:—From the end of January to March, not later than the end of March.

The second crop:—Before the end of July, not later than the end of July.

There are some differences according to localities and climates. In Taichu the best transplanting time is to be found from the seventeenth to the twenty-seventh of February in the first crop and from the twentieth to the thirtieth of July in the second crop, as shown in Table 9.

TABLE 9. Yields of paddy according to the time of transplanting, Taichung.

Crop Season	Dates of transplanting	Yield of paddy per 10a	Number of ears per clump	Number of grains per ear	Dates of heading and its standard deviation	Days from transplanting to heading	Time of harvesting	Days of total growth period	Remarks
First crop	Dec. 29	376	13.5	64.6	Apr. 23.7±3.08	115.7	May 29	151	Variety Taichung No. 65 Days of nursery period 40
	Jan. 8	427	13.6	67.4	27.3±3.36	109.3	June 1	144	
	„ 18	416	13.9	63.3	28.0±2.77	100.0	2	135	
	„ 28	414	13.1	67.0	May 1.2±3.22	93.2	4	127	
	Feb. 7	468	12.6	70.7	2.6±2.23	86.4	4	117	
	„ 17	494	12.9	75.2	9.6±2.17	81.6	16	119	
	„ 27	493	12.7	77.7	16.3±3.15	78.3	23	118	
	Mar. 9	451	11.8	75.4	26.4±2.52	78.4	July 3	116	
	„ 19	402	10.1	80.8	June 1.8±3.38	74.8	12	115	
	„ 29	265	8.9	73.3	8.2±6.74	71.2	24	117	
	Apr. 8	151	9.2	57.8	13.7±10.44	66.7	Aug. 18	132	
	„ 18	101	8.7	50.5	22.1±16.73	65.1	28	132	
Second crop	June 20	414	12.1	80.8	Sept. 6.4±3.03	79.4	Oct. 10	113	Variety Taichung No. 65 Days of nursery period 20
	„ 30	406	11.6	80.5	5.3±3.26	68.2	10	103	
	July 10	423	12.7	76.5	9.9±1.80	62.9	12	95	
	„ 20	443	12.3	77.7	14.1±1.48	57.1	16	89	
	„ 30	431	11.4	80.6	23.9±2.25	56.9	26	89	
	Aug. 9	408	11.2	72.1	Oct. 7.0±2.68	60.0	Nov. 8	92	
	„ 19	298	11.8	64.5	18.1±3.05	61.1	21	95	
	„ 29	189	11.7	41.5	31.1±3.81	64.1	Dec. 6	100	
	Sept. 8	112	12.0	20.6	Nov. 11.9±3.38	65 9	18	102	
	„ 18	17	12.5	—	Dec. 2.3±7.08	76.3	Jan. 4	109	

(2) **Proper young seedling (Days of nursery period)**

First Crop		Second Crop	
Horai varieties	Native varieties	Horai varieties	Native varieties
27–35	33–45	15–20	22–33

There are some differences according to localities and climates.

TABLE 10. Average numbers of Days of Nursery period.
All Agricultural Experiment Stations in TAIWAN, 1935–1939.

Variety	Crop Season	Days of Nursery Period	Days from Transplanting to Heading	Days from Heading to Ripening	Days of Total Growing Period
Horai Varieties	First Crop	34.7	74.4	38.9	148.0
	Second Crop	16.2	58.6	42.3	117.1
	Intermediate Crop	14.0	69.9	35.5	119.3
Native Varieties	First Crop	44.1	84.2	34.7	163.0
	Second Crop	32.5	75.2	34.3	142.5
	Intermediate Crop	39.0	69.9	38.5	147.4

TABLE 11. Days of Nursery Period practiced in local 1935–1939.

Variety	Crop season	Days of Nursery period		Days from Transplanting to Heading		Days from Heading to Ripening		Days of total Growth Period	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Horai variety	First Crop	49.6 (Shin.)	27.0 Tainan)	87.8 (Takao)	61.8 (Taito)	46.7 (Tainan)	34.4 (Takao)	165.6 (Shin.)	135.2 (Taito)
	Second Crop	20.0 (Taichu)	13.0 (Taiho-ku)	63.1 (Takao)	52.0 (Taito)	55.0 (Taito)	34.9 (Taichu)	125.0 (Taito)	98.0 (Shin.)
	Intermediate Crop	14.0	14.0	71.5	67.5	36.5	34.5	122.0	116.0
Native variety	First Crop	52.0 (Tainan)	33.0 (Taichu)	89.9 (Shin.)	82.6 (Taiho ku)	41.0 (Tainan)	29.3 (Takao)	171.6 (Shin.)	153.2 (Takao)
	Second Crop	49.0 (Shin.)	22.0 (Taichu)	92.1 (Takao)	65.0 (Taito)	36.9 (Takao)	31.1 (Karen-ko)	156.4 (Takao)	134.6 (Tai-nan)
	Intermediate Crop	39.0	39.0	79.0	75.0	34.5	28.5	152.0	144.0

Shin....Shinchiku

Seeds :— Two things are required of good seeds. First, they must grow and develop in a normal way, so as to have vigorous germs and a good store of food. Second, vitality must be retained.

Continuing mass selection year by year in the field we can keep the limit with good results and this limit is that of the best strains or genotype in population or variety. Mass selection should be done by selecting large ears of many tillered plants, otherwise the varieties are apt to deteriorate

because correlation coefficients between number of tillers and length of ears or height of culms among varieties show to be very remarkably negative (Table 1).

To get large and plump seeds, selection should be done by strong wind 3–4 times, using fan separater and then it is desirable to select good seeds which have high specific weights using the salt solution. Specific density of those salt solutions are as follows:—

Variety	Specific density	Dose
Non glutinous	1.10–1.13	Water 1 *To* Salt 3-4 *Sho* or 1.0–1.3 *Kan*
Glutinous	1.08–1.10	Water 1 *To* Salt 2-4 *Sho* or 0.8–1.0 *Kan*

Remarks:— *To*=10 *Sho*=18.03904 1; *Kan*=3.75Kg.
After selection the seeds should be washed by water to take off the salt.

The seed in latent life is not dead, for it is capable of living again under suitable conditions of temperature, moisture, supply of oxygen and a peculiar stimulated condition of organized matter, and it is found to be re-excited to activity that is to germinate, and to grow into plant.

So long as that activity may be renewed when the requisite conditions are supplied, so long must the organism be considered as alive though its condition may seem death-like, and all that is necessary is to protect the seeds until such time as it is buried in the soil.

For this purpose thoroughly air-dry the paddy seeds as soon as matured and keep in dry storage or it is better to keep them in dry condition in air-tight, such as a tin can about 1 *koku* volume that is enough seeds per *ko* (i.e. 98% seeds strongly germinated after 32 months in air-tight storage, 1921).

In TAIWAN the seeds of different moisture percentages are stored free in the air and then their moisture, in two or three months, approaches to 13.5–14.0% by the absorption of moisture from the air or by the evaporation of moisture from the seeds and successively fluctuates according to relative humidity of environment, making 13.5–14.0% of their moisture to be the

mode. When even those seeds which have been well dried at the beginning reach 13% of moisture, their respiration becomes vigorous and accordingly the power of germination is apt to decrease and finally dies. When dry paddy seeds contain about 10-11 per cent moisture, it means that hulled rice contains lower per cent moisture than 13%, most seeds retain vitality for many years in air-tight condition (1923).

We can get such seeds by drying one *koku* of paddy seeds spreading on 1.5 *tsubo* of cemented place, stirring once 0.5-1.0 hour in three days, as shown in Table 12.

TABLE 12. Results of drying experiments of paddy seeds, 1922.

(1)

Day of drying	Moisture percentage of seeds					
	First crop season			Second crop season		
	Taipeh Native var.	Taipeh Horai var.	Taichung Native var.	Taipeh Native var.	Taipeh Horai var.	Taichung Native var.
Dry after harvested	28.4	28.4	18.0	16.0	23.2	15.6
First day	20.5	13.2	13.2	12.6	17.2	13.2
Second day	11.5	8.4	10.1	11.6	10.8	11.8
Third day	9.0	6.2	9.3	9.2	9.0	10.6

Remarks:— Temperature in the pile of seeds on drying place, °C, Taipeh.
Average: First crop 42.6; Second crop 31.4.
Surface layer: First crop 46.9; Second crop 34.5.
Center layer: First crop 41.3; Second crop 31.3.
Lowest layer: First crop 39.5; Second crop 28.5.

100 *koku* per 150 *tsubo* of cemented place air-dried in sunny day.
Taipeh, Taichung are expt. places.

(2)

Days of drying by direct sunlight unhulled rice (Taino No. 16)	Moisture percentage hulled rice	Decoloration of methylene blue	Reaction of peroxydase	Clearness of cold water extract of rice	Reducing sugar	Non-reducing sugar and dextrin
(Second crop 1933)	19.35	Weekest	Strongest	Clearest	0.95%	0.78%
First day (45°C)	13.48	Intermediate	Intermediate	Intermediate	0.96	1.38
Second day (45°C)	8.60	Strongest	Weekest	Muddlest	0.91	1.42

TABLE 13. Results of storage experiments of rice.

1. Moisture contents %

Month	First Crop						Second Crop						Remarks
	Hulled rice 15.3–16.4	Unhulled rice 15.7	Hulled rice 13.5–14.9	Unhulled rice 12.1–14.6	Hulled rice 11.5–12.9	Unhulled rice 8.9–11.4	Hulled rice 15.3–15.9	Unhulled rice 15.0	Hulled rice 13.3–14.5	Unhulled rice 12.0–14.4	Hulled rice 9.6–13.1	Unhulled rice 8.4–11.5	
July	**15.83**	15.06	**14.21**	13.44	**12.23**	12.24	14.03	13.55	14.47	13.97	13.25	13.09	1. Averages of 20 Series of Experiments 1921–24. Taichu.
Aug.	15.53	14.88	14.49	13.41	13.28	12.67	14.07	13.42	13.50	13.70	13.06	13.12	
Sept.	14.88	14.12	14.22	13.60	13.66	13.20	13.84	13.36	13.61	13.42	13.15	13.63	
Oct.	14.78	13.73	14.18	13.57	13.79	13.34	13.62	13.24	14.13	13.55	13.00	13.80	
Nov.	14.49	13.76	14.12	13.59	13.85	13.42	13.03	**15.00**	13.53	**13.12**	12.86	**9.81**	
Dec.	14.14	13.63	14.05	13.58	13.94	13.30	**15.60**	13.55	**13.88**	13.00	**11.38**	10.67	2. Showing the Stored Month.
Jan.	14.23	13.85	14.01	14.47	13.90	13.37	15.02	13.42	14.42	12.79	12.29	11.12	
Feb.	14.97	13.76	13.98	13.63	13.87	13.67	14.86	13.48	14.64	13.02	12.68	11.59	
Mar.	14.01	14.06	13.95	13.90	14.08	14.36	14.78	13.00	14.64	13.08	12.83	12.00	
Apr.	14.41	14.85	14.15	14.14	14.29	14.14	14.45	13.42	14.36	13.58	13.16	12.66	
May	14.31	14.64	14.16	13.81	14.05	13.97	14.17	13.42	14.34	13.93	13.61	12.79	
June	13.92	**15.70**	13.91	**13.10**	14.05	**10.42**	14.07	13.30	14.47	13.82	13.43	12.93	
Average	14.57	14.34	14.12	13.68	13.75	13.17	14.29	13.51	14.17	13.43	12.89	12.27	

2. Moisture contents %.

Average of 58 Series of Experiments, Taihoku. 1921–25

Month	First Crop			Second Crop		
	Unhulled rice 15.6–28.0	Unhulled rice 11.8–14.7	Unhulled rice 6.9–10.8	Unhulled rice 15.0–20.4	Unhulled rice 12.4–14.6	Unhulled rice 8.3–11.4
July	**22.00**	**13.40**	**8.50**	13.70	13.30	13.00
Aug.	14.80	13.50	11.50	13.00	13.00	13.00
Sept.	13.80	12.90	11.80	12.90	12.90	12.40
Oct.	13.50	13.10	12.40	13.50	13.10	12.80
Nov.	13.70	13.00	12.50	**17.10**	**13.20**	**9.90**
Dec.	13.70	12.70	12.80	14.60	13.30	11.70
Jan.	13.70	13.20	12.60	13.60	13.40	12.40
Feb.	14.40	13.90	13.20	14.30	13 80	13.30
Mar.	14.40	13.60	13.30	14.70	14.20	13.90
Apr.	14.40	13.80	13.60	14.00	14.30	14.10
May	14.20	13.80	13.20	14.70	14.30	13.50
June	14.30	13.60	13.20	14.20	14.00	13.90
Average	14.72	13.38	12.38	14.19	13.57	12.83

3. Germination

Experiment places	Moisture contents of Seeds at the beginning of Storage %	Month, 1935						Month, 1936					
		July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
		Germination %											
Taipeh (Itahashi)	12.950	90.7	71.0	66.0	69.0	58.0	57.0	49.0	55.0	61.0	49.0	10.0	3.0
Taichung (Shoka)	13.416	94.7	95.0	88.0	86.0	81.0	78.0	87.0	77.0	88.0	71.0	20.0	1.0
Tainan (Ziron)	13.483	—	94.0	67.0	78.0	29.0	71.0	13.0	15.0	15.0	14.0	2.0	3.0
Kuoshung (Heito)	13.483	93.0	92.0	95.0	82.0	53.0	61.0	60.0	52.0	36.0	17.0	16.0	0.0
Average	13.333	93.9	88.0	79.0	78.8	55.3	66.8	52.3	49.8	39.5	37.8	12.0	1.8
		Germination power %											
Taipeh (Itahashi)	12.950	80.0	52.0	47.0	52.0	38.0	40.0	29.0	35.0	48.0	31.0	8.0	1.0
Taichung (Shoka)	13.410	83.5	84.0	79.0	66.0	54.0	64.0	55.0	54.0	59.0	40.0	12.0	0.0
Tainan (Ziron)	13.483	—	90.0	64.0	71.0	19.0	64.0	9.0	11.0	7.0	5.0	1.0	2.0
Kuoshung (Heito)	13.483	81.6	84.0	84.0	65.0	31.0	50.0	34.0	31.0	19.0	7.0	5.0	0.0
Average	13.333	81.7	77.5	77.5	53.4	37.5	46.5	31.8	32.8	33.3	20.8	6.5	0.8
		Moisture content %											
Taipeh (Itahashi)	12.950	12.950	13.640	13.567	13.339	13.116	13.510	13.710	14.207	14.377	13.553	13.400	12.107
Taichung Shoka)	13.416	13.416	13.400	13.024	13.529	12.366	13.454	13.593	13.890	12.932	13.409	13.406	11.640
Tainan (Ziron)	13.483	—	13.483	13.340	13.395	13.276	12.651	13.321	12.889	14.160	13.183	12.754	12.454
Kuoshung Heito)	13.483	13.483	13.760	13.187	13.449	13.329	13.215	13.599	13.370	12.938	12.803	12.707	11.585
Average	13.333	13.293	13.570	13.279	13.428	13.021	13.202	13.555	13.589	13.601	13.237	12.976	11.946

After-ripening of the seeds is accomlished by this drying process (1921). Differences of moisture percentage between hulled and unhulled grains are 0.8–2.1 and 1.5 in average according to their dryness (1922). In Taiwanese climates seeds will generally deteriorate when kept in common storage. They lose about 50% of power to germinate in a few months and 100% in a year (1921, 1939). As there are damp periods of weather now and then, when seeds in storage are quite apt to take up moisture, it is always good to provide free air circulation of dry air in seed houses (1928, 1939).

Cooking quality of white rice in taste is to be deteriorated if dried lower than 13% of moisture in hulled rice, in regard to the physicochemical changes of the constituents, such as starch and proteins, of the grains (1927). The writer projected the *Suboshi* method (halfshading dry method of unhulled rice) to improve the quality of rice. Compare *Suboshi*-rice with direct sun-dried (usual direct sun-light dry method)-rice, the cracking rate of the former is very low and not conspicuous, accordingly the rate of broken rice is very low. Average of cracking rate of commercial rice in Taiwan is 50.20% in the first crop and 30.88% in the second crop. Average of cracking rates of *Suboshi*-rice is 20.31% in the first crop while direct-sun-dried rice is of 49.97% and within 10% in the second crop. Average of broken rice rate of milled white rice is 9.936% in *Suboshi*-rice in the first crop while 34.78% in direct sun-dried rice (1933-1934).

In general direct sun-dried rice is somehow of mealy appearance and inferior to *Suboshi*-rice concerning lustre and taste while *Suboshi*-rice is glassy and of stronger viscosity. This is because that generally in the case of direct sun-dried rice desiccation by high temperature brings physico-chemical change to constituents of rice. The marginal moisture content of rice of this change is about 13.5%. If drying in the direct sun-light is carried on till moisture content falls below 12.0-11.0%, that change is certain. However, in the case of desiccation by low temperature the change is not remarkable. If the temperature of *Suboshi* is compared with that of drying in the direct sun-light, the former is lower than the latter by over 10°C. As far as the difference of chemical constituents between direct sun-dried rice and *Suboshi*-rice is concerned, in the latter case soluble protein is more than in the former case, viscosity of starch is stronger and also there is difference in the absorption power of moisture, in *Suboshi*-rice amylose is less while amylopectine is more than in direct sun-dried rice, in *Suboshi*-rice iodine reaction of starch is very blue while red is less than in direct sun-dried rice, and cold water extract of *Suboshi*-rice is clearer than that of direct sun-dried rice. Regarding taste and viscosity, the longer the period of storage is, the more they decrease. In the

case of air-tight storage, their decrease is slow. The writer stored the well-dried paddy for 10 years in air-tight (1923-33). In 1933 he compared physico-chemically that rice with new harvested rice of the same variety, but he couldn't find any difference between them except viscosity of the former was a little inferior to the latter. Among the experts the value of stored rice was recognized to be the same as that of new harvested rice. The changes of constituents of rice in the storage are inclined to be the same as in the case of drying in the sun-light. And germination rate and both enzymes of peroxydase and catalase decrease their reactions (1933-34).

Soaking the seeds in water before sowing is needed. The number of days of soaking is different according to the temperature of the water. Four days in the first crop and one day in the second crop are preferable. It is necessary to presprout the seeds in the first crop to accelerate the growth of seedlings in nursery because it is cold in that season. In the presprouting process, it is desirable that the lengths of the sprouts are to be 5 mm or so and the lengths of the rootlets 10 mm or so, just twice the lengths of the sprouts. It is preferable to soak the seeds which are soaked one day in water, 3 hours in the dilute formalin solution. It is very effective to kill the spores of rice brust and *Bakanae* (*Giberella Fujikroi* (Sawada) Wk) diseases. Those spores are always to be found on the surface of seeds. The soaking solution per *koku* of seeds is obtained by 1 *sho* of commercial formaldehyde 35% solution multiplying by 5 *to* of water (1 *koku*=10 *to*=100 *sho*=1000 *go*=180.907 litre). Amount of the seeds to be sowet in the nursery is 4-5 *go*, if the seeds are presprouted, 5-6 *go* is needed, per *tsubo* (3.3 m^2), and more preferable 3-4 *go* per *tsubo*. The seeds wanted per *ko* (0.9699 ha) are about 4-5 *to*. Average amount of seeds needed by rice growers is one *koku*, equivalent of the seeds amount for two *ko*, in Formosa. It is likely to be effective, probably on the growth of rootlets of the seedlings, when 0.01 gm of Indolacetic acid or 0.0000001-0.00000001 gm of Naphthalen-acetic acid per *tsubo* is applied in addition to the proper amounts of fertilizers, in the nursery bed. Those should be applied 35 days after sowing in the first crop and 10

days after in the second crop (1944).

Seed bed.

The first crop.

Windbreak :—In the northern and middle parts of the island, during the period of seed bed of the first crop, it is cold and the monsoon blows. Therefore windbreak must be set. The height of the windbreak should be about ten feet. Its effect influences about twenty times the height.

For nursery moderately fertile soil is preferable.

Preparation of soils :—One must do plowing immediately after the harvest time of the second crop. Ten or twenty days before the seeding the second plowing should be done, the third plowing is to be done three days before (it must be very shallow and about three inches and a half in depth), and clods should be broken into pieces. The day before the seeding, irrigate shallowly and do harrowing without drainage. Then on the next morning, that is the day of seeding, that irrigated water is absorbed into soils and the quantity of water becomes proper for bed making.

The quantity of fertilizer per 1/10 *ko* is 3.5-4.0 *kan* (1 *kan*=3.75 Kg) of nitrogen, phosphoric acid, potash separately.

Bed making :—On the day of seeding, around the nursery dig minor ditch one feet and a half in depth, make a one-foot wide ditch every four feet along the windbreak. Scoop up the ditch mud on the surface of the bed. Flatten that surface with a wooden trowel. In this case one must be careful not to walk into on the surface of the bed. If he should leave footmarks on it, he would find sunken places after the preparation of soils and then the growth of seedlings would be ununiform.

Seeding :—After one finishes the bed-making there is to be a little water in the ditches but no water on the surface of the bed. Sprinkle seeds equally all over the surface of one-*tsubo* bed (4 *shaku* × 9 *shaku*, 1 *shaku*=0.30303 m). Stroke the surface with a trowel and press seeds so that one may hardly see them. Then sprinkle burnt dust so that one may hardly see the surface.

Management after seeding :—After seeding, water should be in ditches

so that there may always stand little water. If the water is filled up, let it stand very shallow only in ditches. The degree of dryness over the surface of the bed is different according to the weather. If it is fine, irrigate once every three days and do drainage the next morning. Before the seedlings grow green, roots are not fixed. Therefore when it rains heavily, irrigate and protect the seeds from being put out of the beds.

The second crop.

Preparation of soils :—After the harvest of the first crop, cut out rice stumps at the edge of soils, fill water where they are that the surface of soils may be hidden. Do plowing and harrowing before seeding. Then make seed beds as in the first crop. When one uses the yield of the first crop, dry it fully and use seeds after-ripening.

(3) Proper spacing and depth of transplanting.

Standard spacing of transplanting is as follows :—350～400 seedlings per *tsubo*, 4～5 seedlings per clump and 70～80 clumps or so per *tsubo*, at least more than 60 clumps. Clumps should be planted square way, not irregular. Regular rice planters are to be employed.

Shallow planting is better and it is about 0.5–1.0 inches in depth, except special case. If the seedlings are planted too deep, the secondary roots are used to come out from the upper nodes which are situated on the surface layer of the soil; and the primary roots are to be decayed. The leaves of the seedlings are used to float adhering to water surface when they are planted deep and those leaves never stand up in normal position and at the end they are used to decay.

(4) Standard formula of fertilizer is now expressed in terms of the ratios of total nitrogen (N), phosphoric acid (P_2O_5), and potash (K_2O) in order named. The formula is 10 : 5～10 : 3～10. For example, when 100 Kg of nitrogen (N) is applied per *ko*, 50～100 Kg of phosphoric acid (P_2O_5) and 30～100 Kg of potash (K_2O) should be applied per *ko* according to the kinds of the soils. More potash would be effective in the period of rapid growth in hot climate as in the second crop season.

Practically the followings are recommended as a safe amount :— By chemicals or soy bean cake, N 52～56 Kg, P_2O_5 26～56 Kg, K_2O 15～56 Kg, adding to these 12,000～18,000 Kg of manure.

Manure contains 0.4 percent of nitrogen, 0.3 percent of phosphoric acid, 0.5 percent of potash in average. It is necessary that we should give the manure more than 15000 Kg per *ko* a year to prevent the deterioration of soil fertility because of rapid decomposition of humus in the soil in tropics, otheruise it makes the soil very poor.

It is good to grow green manure crops during winter, such as pea, soy bean, Sesbania and Raphanus sp. (*Densei*), single or mixed. Leguminous green manure crops contain 0.5-0.8 per cent of nitrogen, 0.1 per cent of phosphoric acid and 0.5 per cent of potash in average. The plowing-under of such winter crops adds nitrogen as well as organic matter to the soil. The feeling is that the organic materials, being less soluble, are ordinarily available to the plant over a longer period of time than the inorganic constituents, which, being more soluble, are quickly available. But in Taiwan, the tropical region, nitrogen in green manure crops is quickly available to the rice plant, as well as the nitrogens of ammonium sulphate or soy bean cake.

Nitrogen fertilizers should be plowed in all the layers of cultivated soil, otherwise about half a part of compound nitrogen which is supplied to the soil is usually driven off, being changed to nitrogen gas by the chemical reaction which occurs in the place between the upper layer of the cultivated soil and the under layer of irrigation water.

Two-third of the total fertilizer should be applied preceding the transplanting and one-third, as a top-dress, should be applied early, at least until before the second weeding.

(5) Deeper plowing than usual is desirable when the development of the root system is considered and an abundant supply of manure is more desirable. Because when the deep plowing is accompanied by supply of manure it is very effective to improve the soil rich.

TABLE 14. Preparation of soil

Crop Season	Preparation of soil, plowing and harrowing		
	First	Second	Last
First Crop	After harvested second crop	10-20 days before transplanting; manuring and irrigation	Right before transplanting; rolling to flatten the soil; Extra to be done between the second and the last
Second Crop	After harvested first crop; irrigation; stumps of first crop are to be rotton	7-10 days before transplanting; rolling to flatten the soil	

(6) Keep the depth of irrigation water as possible as shallow at the time of transplanting and about two weeks later, then 1.0-1.5 inches deep until the stage of heading to milk ripe. Drain the water after this stage considering to keep soil wet and to prevent the surface soil from cracking on accunt of dry weather. If it is too dry, irrigation is necessary to prevent cracking.

(7) The first weeding should be done at the fifteenth day after the transplanting in the first crop and at the tenth day in the second crop. The next weeding should be followed successively in every ten days in the first crop and every seven days in the second crop. The rice weeders are employed as well as hand weeding. Late weeding in the season when the plants are abundantly tillered and grow up vigorously, usually tends in turn to give more damage to culms and root growth than from weed growth. Drain the irrigation water preceding the weeding and leave the field as it is one or two days after the weeding and then irrigate again as usual.

TABLE 15. Some estimations of the Yield of hulled rice per *ko*.
(Complete data are to be found in Literature No. 34)

Number of clumps per *tsubo*	Number of grains per ear	Number of ears per clump											
		11		12		13		14		15		16	
		Number of ear per *tsubo*	Yield of hulled rice per *ko*	Number of ear per *tsubo*	Yield of hulled rice per *ko*	Number of ear per *tsubo*	Yield of hulled rice per *ko*	Number of ear per *tsubo*	Yield of hulled rice per *ko*	Number of ear per *tsubo*	Yield of hulled rice per *ko*	Number of ear per *tsubo*	Yield of hulled rice per *ko*
60	55	660	15.832 (13.017)	720	17.271 (14.200)	780	18.710 (15.388)	840	20.149 (16.560)	900	21.538 (17.751)	960	23.028 (19.934)
	60		17.271 (14.200)		18.841 (15.491)		20.411 (16.783)		21.981 (18.077)		23.554 (19.404)		23.121 (20.655)

65	55	715	17.151 (14.102)	780	18.710 (15.384)	845	20.269 (16.666)	910	21.828 (17.948)	975	23.386 (19.230)	1040	24.947 (20.512)
	60		18.710 (10.388)		20.411 (16.783)		22.112 (18.181)		23.813 (19.579)		25.514 (20.978)		27.215 (22.377)
70	55	770	18.470 (15.187)	840	20.149 (16.567)	910	21.828 (17.948)	980	23.508 (19.328)	1050	25.286 (20.709)	1120	26.866 (22.090)
	60		20.149 (16.567)		21.981 (18.077)		23.813 (19.579)		25.646 (21.086)		27.476 (22.592)		29.308 (24.098)
75	55	825	19.790 (16.272)	900	21.589 (17.751)	975	23.386 (19.230)	1050	25.286 (20.109)	1125	26.986 (22.189)	1200	28.786 (23.663)
	60		21.589 (17.751)		23.554 (19.404)		25.614 (20.978)		27.476 (22.592)		29.440 (24.206)		31.402 (25.819)
80	55	880	21.109 (17.355)	960	23.028 (18.934)	1040	24.947 (20.512)	1120	26.866 (22.090)	1200	28.785 (23.668)	1280	30.704 (25.240)
	60		23.208 18.934		25.121 (20.655)		27.215 (22.377)		29.308 (24.098)		31.402 (25.819)		33.495 (27.541)

Remarks:—Number of unhulled rice in one *sho.*—Horai rice 37,000, native rice 45,000.
Volume ratio of hulled grain to unhulled grain 55%
1 *sho*=1.80391 l 1 *tsubo*=3.30579 m^2; 1 *koku*=100 *sho*=1.80391 kl
1 *ko*=0.9699 ha, ( )=native rice

VI. A RESULT OF APPLICATION OF A PRACTICAL PROBLEM IN TAIWAN

One of the most striking problems of recent agriculture in Taiwan is the rapid increase of rice production of Japanese varieties. We gave them the name "Horai Rice"—which is giving a great benefit not only to the rice producers and the rice exporters but to the development of economics of this island. Until recent times Formosan rice has been represented by 175 varieties. The number of the native varieties was 1197. A newer production gave about five million *koku* and about one million *koku* were exported to Japan, but its market price in Japan was always much lower than Japanese rice because of its inferior quality. The same thing is applied to Burma, Siam, and Saigon rice.

This was about 25 years ago and at that time the population of Formosa was about five million. Therefore people have been making great effort to be

successful in production of Japanese varieties for thirty years, but they always failed practically.

Before we explain the Japanese varieties, the writer must ask all the readers' attention to some characteristics of Formosan varieties which have become well adapted during many years. It is very necessary to understand the general principle of the application of experimental results. In Taiwan all varieties were settled in all crop seasons.

In one season people never planted the varieties which belonged to the other season. Because if they planted the second crop varieties in the first crop season, it would mean failure to get the yield in that season. The second crop varieties response heading as very sensitive as Japanese varieties to the short day. But the lengths of days in May and June are still too long to be head for the second crop varieties though the first crop varieties and Japanese varieties response heading to the day lengths in May and June.

TABLE 16. Temperature and Length of Day in Taichung (Taiwan) Compared with those in Tokyo and Saigon.

	Temperature (°C)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann. Ave.
Taichung	15.7	15.4	18.1	21.8	25.0	26.7	27.6	27.3	26.3	23.6	20.2	17.1	22.1
Tokyo	3.1	3.7	6.9	12.6	16.7	20.5	24.3	25.6	22.0	16.0	10.6	5.4	14.0
Saigon	25.8	26.7	27.8	28.9	28.0	27.2	26.7	27.0	26.6	26.5	26.3	25.8	26.9
	Length of Day (Hours)												Lati-tude
Taichung	10.78	11.34	11.98	12.69	13.27	13.57	13.43	12.92	12.24	11.55	10.92	10.62	N24.00
Tokyo	9.95	10.38	11.92	13.09	14.05	14.55	14.31	13.46	12.35	11.22	10.20	9.67	N35.41
Saigon	11.52	11.75	12.03	12.32	12.59	12.73	12.67	12.45	12.13	11.85	11.59	11.47	N10.47

Remarks:— Complete data are to be found in Literature No. 34.

The writer had studied the days of common growth period of all crops and he had marked out their average number such as:-

(1) The first crop 165 days

(2) The second crop 135 days

(3) The intermediate crop 140 days.

But when he planted these kinds of varieties in the first crop season, he found that the days of growth period of second crop varieties were always greater than the other two varieties and headed in September. The first crop varieties had always the shortest day period. But when he planted the same kinds of varieties in the second crop season, he found that the days of growth period of second crop varieties were always a little shorter than the other two kinds of varieties, because of its sensitive response to the short days in the fall. He also studied the days of common nursery period of all crops and worked out a result such as:—

First crop—60 days in the fall, winter or early spring.

Second crop—30-40 days in summer.

Intermediate crop—40 days in later spring or early summer.

When he planted 30 day nursery plants of the first crop varieties in the second crop season, he found that the growth period and length of culm had been shortened, and when he planted 60 day nursery plants of the second crop varieties in the first crop season, he found that the growth period and length of culm had been prolonged. It was impossible to get a yield in that season. When he planted 60 day nursery plants of the intermediate crop varieties in the first crop, he found the growth period and the length of culm had been prolonged. But, on the contrary, when the 30 day nursery plants were planted in the second crop season, he found that there were reversible responses in the case of the first crop season. These phenomena in each case, are due to the difference of responses of different characters according to growth period and inadequacy of abnormal length of nursery period.

Now, let me return to Japanese varieties. They are found to be earlier varieties than Taiwanese varieties. Therefore, when the writer planted those varieties in the same nursery period, he found that there was great increase of deviation of tillering and heading and decrease of length of culms, especially in the second crop season. This is true of all first and second crops in the southern tropical parts. In view of the marked influence

of length of nursery period and the growth of Taiwanese varieties it seemed to be likely that Japanese varieties would be found to respond to the influence in the same economical way if they were given the optimum nursery days. Accordingly in the year 1922 a series of experiments was made to test their effects of shortening the length of the nursery period from 25 to 30 days in the first crop and 15-20 days in the second crop.

Those seedlings had low carbon-nitrogen ratios in their chemical contents. At last he reached success which gave the great demonstration to the people.

1. The height of the plant was great
2. Many available tillers
3. Small deviation of heading
4. Heavy ears

A great yield of Japanese varieties was harvested exceeding that of the Taiwanese native varieties. Japanese varieties were more productive than the native varieties especially in rich soil or especially in the case when a plenty of fertilizers was given. This method was applied to the Japanese varieties and even applied gradually to the native varieties in the same way. People had shortened the length of the nursery period of the native varieties to 44.1 days in average, 33 days minimum in Taichung prefecture, 52 days maximum in Tainan prefecture in the first crop and to 32.5 days in average, 22 days minimum in Taichu prefecture, 49 days maximum in Shingchu prefecture in the second crop. (Table 11) As a whole, it is recognized as a result that the shortening of the nursery period gives a great increase of grain production. About ten years after, the annual production of rice in Taiwan, increased from 5 million *kokus* (1 *koku*=1.80391 Kl) to near 10 million *kokus* and the " Horai Rice " constitutes the greater part of rice exportation about 5 million *kokus*, 130-170 million *yen* a year because of its high commercial price in Japan market.

Average index number of the price of the Horai Rice was 80-90% of the Japanese rice when the native rice was 50-60% and average income of

growers per *ko* (*ko*=0.9699 ha) has shown 133.5 against 100 of the native rice. For the development of the Horai Rice, the writer and his co-workers continued to pay great efforts to crossbreed many superior Horai varieties and at present those varieties are distributed through the Island. He was preparing for crossbreeding between the Horai and the southern tropical varieties or the Formosan native varieties, according to the conception of his previous researches. One aim is to get more resistant Horai varieties against the rice blust in the first crop season and sclerotial stem rot in the second crop season. The other is to breed new Horai varieties from which he might get young taller seedlings which keep the carbon-nitrogen ratio low though they stay in nursery for a long period. If he could reach success, it would be very easy for the growers to do transplanting work and to get heavy yield of commercial grain.

The other of the striking problems of recent agriculture in Taiwan is the rapid increase of winter catch crop production in the two rice crop fields and sugar cane field, the sugar cane which is found growing in the rice field as a rotation crop of the rice. When the Horai rice, the earlier varieties than the natives, was distributed in general, there was to be found usually no crop planted in the past November to February or the beginning of March, about 3.5-4.0 months, except green manure crops or a few crops in some part. Twenty five years ago, the writer proposed to study the catch crops in this season and he continued the experiments by his project. It was not only the catch crops of the two rice crop fields, but the catch crops between the ridges of sugar cane planting, at the early stage of its growth, from September to March of the next year. He and his co-workers reached to success on the breeding and cultural procedures of those crops and recommended them to the rice growers. Among those catch crops, new varieties of sweet potatoes were already distributed in general, buckwheat and new crossed varieties of spring wheat are very promising and are being distributed at present, many kinds of vegetables are now growing everywhere, and the flax is very promising as an industrial crop in the near future.

The writer expects that the rice growers could get the highest profit as a whole from their own field along this project and a great development and prosperity of Taiwanese subtropical agriculture.

This bulletin is like a brief summary of the above-mentioned themes. If one wants to know the particulars and others, he must refer to Literatures No. 16, 34, 35.

TABLE 17. Frequency distribution of the yield of rice per *ko.*

1. The Native Variety (1919)

Crop Season	No. of Varieties	Frequency distribution of the yield of unhulled rice per *ko.* (*Kan*=3.75kg)																					Average	
		40—45	45—50	50—55	55—60	60—65	65—70	70—75	75—80	80—85	85—90	90—95	95—100	100—105	105—110	110—115	115—120	120—125	125—130	130—135	135—140		unhulled rice (*Kan*)	hulled rice (*Koku*)
First Crop	140	2	—	4	4	8	11	18	10	28	19	13	11	1	3	5	1	2	—	—	—		81.750 (3065kg)	16.249
Second Crop	178	2	4	6	2	7	13	22	21	22	28	16	13	5	5	3	2	—	—	—	1		81.483 (3055kg)	16.197
Intermediate Crop	24	1	1	1	2	3	2	1	6	5	3	1	—	—	1	—	—	—	—	—	—	—	70.542 (2645kg)	14.019

2. The Japanese Variety (1924-25)

Crop Season	No. of Varieties	Frequency distribution of the yield of unhulled rice per *ko.* (*Kan*=3.75kg)																				Average	
		30—35	35—40	40—45	45—50	50—55	55—60	60—65	65—70	70—75	75—80	80—85	85—90	90—95	95—100	100—105	105—110	110—115	115—120	120—125	125—130	unhulled rice (*Kan*)	hulled rice (*Koku*)
First Crop	178	—	—	—	1	1	1	2	1	8	7	15	11	30	28	29	22	13	4	1	3	88.219 (3308kg)	17.594
Second Crop	183	3	2	1	—	6	6	8	7	12	17	33	37	25	14	9	3	—	—	—	—	73.303 (2748kg)	14.538

3. The Horai Variety (1922-1943

Crop Season	No. of Varieties	Frequency distribution of the yield of unhulld rice per *ko*. kg.																Average	
		2000—2200	2200—2400	2400—2600	2600—2800	2800—3000	3000—3200	3200—3400	3400—3600	3600—3800	3800—4000	4000—4200	4200—4400	4400—4600	4600—4800	4800—5000	5000—5200	unhulled rice (Kg)	hulled rice (*koku*)
First Crop	126	3	1	1	1	4	9	19	17	17	22	18	6	5	1	—	2	3660	19.455
Second Crop	126	4	2	14	7	21	9	18	16	18	8	4	3	1	—	—	—	3329	17.636

Remarks: 33 Varieties—pure line Selection of Japanese Varieties
93 Varieties—Crossbred

TABLE 18. Chemical Analysis of the Horai and the Japanese rices

Varieties	Size of grain (weight of 1000 grains)	Shape of grain (Length: Breadth)	Moisture Content	Nitrogen in crude protein	Nitrogen in pure protein	Nitrogen in Non-protein	Crude fat	Ash	Starch	Reducing Sugar	Nonreducing Sugar and dextrine
Horai rice	gm		%	%	%	%	%	%	%	%	%
Taichung No. 65 1934	24.25	1.70	15.38	1.65	1.62	0.03	3.18	1.54	81.08	0.84	1.30
Japanese rice Rikuu No. 132 1934	22.50	1.69	15.73	1.47	1.42	0.05	3.25	1.54	80.72	0.82	1.25

TABLE 19. Viscosities and iodine reactions of the Horai and the Japanese rices

Varieties	Number of Samples	Moisture Content	Ash	Viscosity 2% Solution of Starch: water (35°C)			Keeping power of Viscosity; Index in 100 (15°C)			Iodine reaction blue: red
				Mean	Max.	Min.	First day	Second day	Third day	
		%								
Commercial Horai rice 1934	22	13.77	0.376	9.30	15.95	7.11	100.0	97.89	94.44	11.69
Commercial Japanese rice 1934	5	15.05	0.400	11.52	15.10	8.87	100.0	97.02	95.06	12.40

TABLE 20. New Crossed Varieties under Local Experiments 1945

Names of New Crossed Varieties		Names of Parents ♀ × ♂	Remarks
Taipeh	No. 7	Taipeh No. 6×Taipeh No. 5	Taipeh No. 6=Kyonishiki×Osaka Asahi; Taipeh No. 5=Meijiho×Yokichisen
	No. 8	〃	
	No. 10	Kyonishiki×Kagi Ban No. 2	
Shingchu	No. 4	Tainong No. 16×Taichung No. 65	Tainong No. 16=Shimehari×Kagi Ban No. 2; Taichung No. 65=Kameji×Shinriki
Taichung	No. 150	Selected from Taichung No. 114	
〃	No. 152	Taichung No.115×Taichung No.121	Taichung No. 114=Taichung No. 65 ×NC No. 4; Taichung No. 115=NC No. 4 ×Taichung No. 65; Taichung No. 121=Taichung No. 65×Taichung No. 111; Taichung No. 111=Chungtzong ×Taichung toku No. 2; Taichung toku No. 2=Selected from Shinriki
〃	No. 155	〃	
Chianan	No. 1	(Go-nug-chut×mii)×Taichung No. 65	
〃	No. 2	〃	
〃	No. 5	〃	
〃	No. 7	〃	
〃	No. 8	〃	
Kuoshung	No. 10	Kairyo aikoku×Kuoshung No. 6	Kuoshung No. 6=Takenari×Kinai chusei No. 76
〃	No. 11	Aikoku×Kuoshung No. 6	
〃	No. 18	Kuoshung No.10×Taichung No.114	
Tainong	No. 37	Iyo sengoku×Tango chuto	
〃	No. 36	Taichung No. 65×Iwata asahi	
〃	No. 40	(Toyokuni×Iwata asahi)×Taichung No. 65	
〃	No. 41	〃	
〃	No. 42	〃	
〃	No. 45	Tainong No. 16×Taichung No. 65	
Shingchu Glutinous	No. 2	Heiroku Mochi×Kamenoo	
〃	No. 3	Heiroku Mochi×Asahi	
Taichung Glutinous	No. 59	Hassen Mochi×Taichung toku No. 6	Taichung toku No. 6=Selected from Asahi
〃	No. 60	Hassen Mochi×Taichung No. 114	
〃	No. 61	Taichung Mochi No. 49×Taichung Mochi No. 46	Taichung Mochi No. 49=Taichung Mochi No. 35×Seino Mochi
〃	No. 62	Taichung Mochi No. 46×Taichung Mochi No. 49	Taichung Mochi No. 46=Taichung Mochi No. 35×Taichung No. 65
〃	No. 63	Taichung Mochi No. 49×Taichung No. 65	Taichung Mochi No. 35=(Miyako ×Chian-Go-Nug-Chut)×Taichung toku No. 2
Tainong Glutinous	No. 5	(Yanagi Mochi×Tainong No. 16)×Hassen Mochi	
〃	No. 6	〃	
〃	No. 7	(Tainong No. 16×Meishin Mochi)×Hassen Mochi	

TABLE 21. Results of high yield competition of rice applying the above-mentioned procedures.
Agricultural Association, Taiwan.

1. Yield of Rice per *ko* (0.9699 ha

Crop season	Year	Yield per *ko* (*koku*, 1.8039 hl)			Number of Points	Remarks
		Average	Min.	Max.		
First Crop	1942	39.017	20.175	59.418	27	One point per district
	1943	42.501	32.262	55.279	30	
Second Crop	1942	41.558	27.855	58.485	10	2 variety Horai rice
	1943	40.013	26.892	68.496	11	
Total	1942	87.726	70.562	108.801	10	
	1943	87.567	68.453	120.784	11	

2. Amount of seeds per *tsubo* in nursery.

Crop season	Year	Amount of seeds per *tsubo* (*go.*=1/1000 *koku*)		
		Average	Min.	Max.
First crop	1942	4.49	2.5	4.8
	1943	2.97	0.6	5.0
Second crop	1942	2.05	1.5	3.5
	1943	3.14	2.0	5.0

3. Days of nursery period

Crop season	Year	Days of nursery period		
		Average	Min.	Max.
First Crop	1942	33.071	25	45
	1943		30	40
Second Crop	1942	17.714	13	25
	1943		13	20

4. Depth of plowing (*Shaku*, 0.30303 m)

Crop season	Year	Depth of plowing		
		Average	Min.	Max.
First crop	1942	—	0.80	1.50
	1943	1.31	0.80	2.50
Second crop	1942	—	0.60	1.80
	1943	1.24	0.80	2.00

5. Spacing, number of clumps per *tsubo*.

Crop season	Year	Number of clumps per *tsubo*		
		Average	Max.	Min.
First crop	1942	72.35	90.0	55.6
	1943	79.04	101.4	46.0
Second crop	1942	83.54	108.8	58.5
	1943	77.34	90.0	62.3

6. Fertilizer applied per *Ko*.

Crop season	Year	Average (*Kan*; 3.75 Kg)		
		N	P_2O_5	K_2O
First crop	1942	165.288 (100)	137.394 (83)	198.760 (120)
	1943	269.329 (100)	218.116 (73)	426.972 (143)
Second crop	1942	90.305 (100)	69.502 (77)	112.328 (124)
	1943	250.467 (100)	228.521 (91)	461.882 (183)

N		P_2O_5		K_2O	
Min.	Max.	Min.	Max.	Min.	Max.
39.703	880.323	24.943	776.413	17.808	779.403
85.612	600.472	68.949	397.580	77.728	857.573
12.580	195.415	7.410	182.750	3.384	354.856
122.062	599.560	76.902	551.008	156.522	774.189

Percentage of	Percentage of farm manure		
	N	P_2O_5	K_2O
76.23	61.68	76.01	84.94
67.80	71.90	70.10	78.90
81.05	51.95	64.42	74.33
60.50	67.30	62.46	71.80

VII. STATISTICS OF RICE PRODUCTION IN TAIWAN.

TABLE 22. Yields of Rice per *Ko* (0.9699 ha .

		Yield per *Ko*	
		Actual number *Koku* (1.8039 kl)	Index in 100
Average in Taiwan	1939	14.1770	67.10
Average in Japan	1939	21.1278	100.00
Average of 64 maximums in Formosa one point per district)	1931	37.2110	176.12
Maximum in Japan	1929	84.0000	397.58
Maximum in Taiwan (From the same field	1942		
1 st Crop		49.5960	234.747
2 nd Crop		58.4850	276.816
Total		108.0810	511.563
Maximum in Taiwan (From the same field	1943		
1 st Crop		52.288	247.484
2 nd Crop		68.496	324.198
Total		120.784	571.683

Remarks:— In the cases of 65–85, number of clumps per *tsubo;* 75–80, average number of grains per ear; and 19–22, average number of tillers per clump; 50–60 *koku* or so of Horai Rice per *ko* are to be harvested by growers.

TABLE 23. Rice Production in Taiwan

5 Year average	Low land rice					
	Horai Rice		Native Rice		Glutinous round	
	Planted area	Yield	Planted area	Yield	Planted area	Yield
	ko	*koku*	*ko*	*koku*	*ko*	*koku*
1900 — 1904	—	—	324.614	2.818.134	24.122	173.706
1905 — 1909	—	—	411.678	3.901.917	26.933	226.712
1910 — 1914	—	—	421.007	3.985.571	32.735	276.390
1915 — 1919	—	—	411.670	4.126.286	42.574	377.662
1920 — 1924	9.296	131.087	420.717	4.381.365	58.433	521.490
1925 — 1929	106.638	1.296.059	353.512	4.053.062	74.074	754.897
1930 — 1934	196.717	2.874.025	337.278	4.038.362	74.979	738.642
1935 — 1939	308.907	4.728.256	262.400	3.437.092	54.727	690.012
1940 — 1943	370.889	4.931.660	232.420	2.773.662	15.956	189.206
Year of highest production 1938	310.721	5.276.323	255.170	3.609.525	40.378	576.135

5 Year average	Low land rice				Upland Rice	
	Glutinous long		Total		Non-glutinous	
	Planted area	Yield	Planted area	Yield	Planted area	Yield
	ko	*koku*	*ko*	*koku*	*ko*	*koku*
1900 — 1904	—	—	348.736	2.991.840	30.841	169.856
1905 — 1909	—	—	438.611	4.134.629	40.236	271.204
1910 — 1914	—	—	453.742	4.256.961	40.621	236.721
1915 — 1919	—	—	453.244	4.503.918	39.634	243.132
1920 — 1924	—	—	488.446	5.033.894	38.467	243.511
1925 — 1929	19.918	216.191	554.142	6.321.139	36.698	278.385
1930 — 1934	19.782	232.738	628.756	7.883.766	41.088	353.746
1935 — 1939	13.349	167.963	639.383	9.093.323	34.076	279.071
1940 — 1943	6.572	81.317	625.837	7.975.845	21.304	116.799
Year of highest production 1938	10.564	136.592	616.834	9.598.675	27.662	215.962

5 Year average	Upland Rice				All Total	
	Glutinous		Total			
	Planted area	Yield	Planted area	Yield	Planted area	Yield
	ko	*koku*	*ko*	*koku*	*ko*	*koku*
1900 — 1904	2.623	13.165	33.464	183.021	382.200	3.174.861
1905 — 1909	2.756	13.597	42.931	281.801	461.602	4.424.430
1910 — 1914	2.637	16.132	43 258	252.873	497.000	4.309.834
1915 — 1919	2.981	17.771	42.615	260.903	496.859	4.764.821
1920 — 1924	1.781	10.244	40.248	253.755	528.614	5.287.649
1925 — 1929	1.414	10.029	38.112	288.414	590.254	6.609.553
1930 — 1934	1.504	10.547	42.592	366.293	671.348	8.250.059
1935 — 1939	676	5.467	34.750	284.538	674.135	9.377.861
1940 — 1943	113	463	21.417	117.262	647.254	8.093.107
Year of highest production 1938	296	2.362	27.959	218.324	644.793	9.816.899

Remark:— Recently glutinous round is all glutinous Horai.

TABLE 24 Average income per *ko* during 1921—43

Year	Crop Season	Horai rice	Native rice	Horai Index in 100 to Native
		yen	*yen*	
1921	First Crop; 1	—	167.8	—
	Second Crop; 2	—	175.0	—
1922	1	—	196.6	—
	2	—	120.5	—
1923	1	—	188.6	—
	2	—	143.0	—
1924	1	—	234.1	—
	2	349.5	249.5	140
1925	1	495.7	475.2	104
	2	346.0	257.5	137
1926	1	307.0	272.5	113
	2	275.0	219.4	155
1927	1	320.0	223.0	144
	2	267.0	175.0	153

Year	Crop Season	Horai rice	Native rice	Horai Index in 100 to Native
		yen	*yen*	
1928	First Crop; 1	250.0	212.0	118
	Second Crop; 2	247.3	211.0	117
1929	1	260.5	222.2	117
	2	296.0	206.0	144
1930	1	278.8	201.4	138
	2	169.4	122.3	138
1931	1	195.7	129.1	152
	2	143.2	104.6	137
1932	1	241.0	188.2	128
	2	234.7	173.0	132
1933	1	224.7	167.9	134
	2	230.0	157.6	146
1934	1	258.0	203.1	143
	2	303.3	202.9	149
1935	1	322.0	258.3	135
	2	318.0	243.2	131
1936	1	417.6	316.0	132
	2	304.0	235.7	129
1937	1	387.5	276.0	140
	2	340.0	250.8	136
1938	1	436.0	336.5	130
	2	380.0	309.0	123
1939	1	428.2	345.8	124
	2	400.0	326.0	123
1940	1	435.0	326.4	133
	2	298.0	252.7	118
1941	1	443.0	347.0	128
	2	365.8	329.2	111
1942	1	439.1	371.0	118
	2	408.0	312.2	131
1943	1	478.4	374.0	128
	2	429.5	332.4	129
Average				133.5

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Following table contains corresponding Japanese readings of some proper nouns in this paper for the convenience of the references.

	Japanese reading
Chianan	Kanan
Chungtzong	Nakamura
Kuoshung	Takao
Shingchu	Shinchiku
Taichung	Taichu
Tainong	Taino
Taipeh	Taihoku